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ONTARIO

Department of Education

Courses of Study

Grade XIII

CHEMISTRY

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CHEMISTRY, GRADE X111,

This course in Chemistry is a continuation of that prescribed in Grades XI and XII (Chemistry or Agriculture, Part II). It is outlined in detail in order to give the teacher a definite guide as to what topics should be studied. The number of periods (each of 40 minutes) given is merely a suggestion or guide as to the "depth" of treatment. Some topics might require more time while others could be shortened.

The sequence of topics as presented is suggested as a logical arrangement, but may be varied at the discretion of the teacher. The periodic classification of elements, for instance, may be taught whenever the teacher considers it most satisfactory. Fundamental principles and experimental work should be emphasized. Pupils should be encouraged to use books of reference.

Review. (Twenty periods.)

In order to give pupils an opportunity to refresh their knowledge of laboratory technique and to review certain elementary chemical principles and equations, the following experiments are suggested:

(1) The preparation and collection of oxygen and the formation of one acidic and one basic oxide.

(2) The preparation and collection of hydrogen. Demonstration of the "reduction" of cupric oxide, using dry hydrogen.

(3) The reduction of cupric oxide by powdered charcoal.

(4) The preparation of acetylene and its complete and incomplete combustion.

(5) The combustion of copper in sulphur vapour.

During the discussion of the above experiments, opportunities will occur for the review of (i) the states of matter, (ii) the characteristics of pure substances, mechanical mixtures and solutions, (iii) exothermic and endothermic reactions.

The preceding, or any other experiments, may be used as a basis for the study of the following:

Law of Reacting Weights
Molecular Weights
Gay-Lussac's Law of Combining Volumes.

SIMPLE PROBLEMS:

(a) To find (1) the reacting weight of an element from the composition of its oxide, (2) the simplest formula from the percentage composition, (3) the percentage composition of a compound from its formula.

(b) To determine molecular formulae.

(c) To calculate from equations representing reactions the proportion by weight and by volume of the pure substances involved in these reactions.

Factors Affecting Rate of Reactions. (Five periods.)

A study of the effect of (1) heat, (2) light, (3) concentration, (4) surface area, (5) catalysis, on the rate of reaction.

The following experiments are suggested:

(1) Heat; the gradual heating of crystals of ammonium dichromate by means of (a) the flame of a candle, (b) the flame of an alcohol lamp or Bunsen burner.

(2) Light; the effect of light on freshly precipitated silver chloride.

(3) Concentration; recall the burning of substances in air and in oxygen.

(4) Surface Area; the addition of acid to equal weights of crystalline and of powdered washing soda.

(5) Catalysis; recall the action of manganese dioxide on heated potassium chlorate.

(6) The effect of various factors combined as shown by the action of oxalic acid and sulphuric acid on a solution of potassium permanganate.

Equilibrium. (Seven Periods.)

Recall the vaporization of bromine in a stoppered bottle partly filled with liquid bromine (Change of State, Grade XI).

Equilibrium as illustrated by the vapour pressure of benzene and of water as determined by introducing a few drops of (1) benzene, (2) water, into the vacuum of a mercury barometer. The effect of changing the temperature in displacing the equilibrium should be shown (the barometer tube may be fitted into a Liebig condenser jacket and the temperature changed by hot or cold water).

Reversible reactions and conditions that affect equilibrium, as illustrated by (a) water $\rightleftharpoons$ water vapour, (b) ice $\rightleftharpoons$ water, (c) sugar (solid) $\rightleftharpoons$ saturated solution of sugar, (d) hydrated copper sulphate $\rightleftharpoons$ anhydrous copper sulphate and water, (e) calcium carbonate $\rightleftharpoons$ calcium oxide and carbon dioxide, (f) solutions of ferric chloride and ammonium thiocyanate $\rightleftharpoons$ ferric thiocyanate and ammonium chloride.

Atoms and Molecules. (Four periods.)

Recall the Law of Reacting Weights and Gay-Lussac's Law of Volumes; a brief discussion of the molecular and atomic theories in relation to these laws.

Review the "Conductivity of a Gas" (Physics, Grade XII) to show that an atom is not indivisible. In gases conducting an electric current an atom breaks into positively and negatively charged particles. The electron is common to all atoms and has negligible mass. The positively charged part (the nucleus) carries almost the whole mass. A concept of the structures of the hydrogen and chlorine atoms with respect to the nucleus and electrons (a plane projection of the Bohr concept is suggested).

Heavy water and the isotopes of hydrogen; isotopes of chlorine. Isotopes differ only in atomic weight (mass of the nucleus) and scarcely at all in properties (electron structure). Canadian production of uranium and radium. Characteristics of radio-active disintegration. Uses of radium.

NOTE.—It should be stressed that ideas of the arrangement of nucleus and electrons are constantly changing.

The Theory of Ionization of Acids, Bases and Salts.
(Eight periods.)

A demonstration of the electrolysis of cupric chloride (using carbon electrodes), with an explanation in terms of charged particles.

Recall the structure of the hydrogen atom (one valence electron) and the chlorine atom (seven valence electrons).

A discussion of the formation of the hydrogen chloride molecule by the lending of the hydrogen electron to the chlorine atom to complete the stable octet.

The tendency of the hydrogen atom to lend an electron to form the hydrogen ion.

A discussion of the dissociation of hydrogen chloride when dissolved in water as giving rise to electrically charged particles or ions.

A discussion of the hydrogen ion as being the characteristic ion of acids, and of the properties of acids (taste, effect on litmus and other indicators, action on metals, etc.) as being due to hydrogen ions in the solution.

A discussion of the ionization and electrolysis of common salt solution and the importance of the products.

Experimental study of the equilibria: (a) cupric bromide molecules $\rightleftarrows$ cupric ions and bromine ions (as shown by change of colour on dilution), (b) barium chloride molecules $\longleftarrow$ barium ions and chlorine ions (as shown by the addition of concentrated hydrochloric acid to a saturated solution of barium chloride).

A brief discussion of the measurement of degree of acidity in terms of hydrogen-ion concentration, and of degree of basicity in terms of hydroxyl-ion concentration.

The meaning of the terms "concentration" and "strength" (hydrogen-ion or hydroxyl-ion concentration) as applied to acids and bases.

Neutralization.
(Five periods.)

Experiments to show the neutralization reaction between acids and bases: the products of the reaction—water, and a salt which is left as a residue on evaporation of the water.

A discussion of neutralization as being a quantitative reaction depending on the removal of the hydrogen ions and hydroxyl ions to form water.

Experiments to show the volumes of sulphuric acid, nitric acid and hydrochloric acid, respectively, which will be necessary to neutralize any known weight of sodium hydroxide or potassium hydroxide dissolved in any quantity of water.

NOTE—The information (specific gravity, percentage by weight) given on the labels of acid bottles shows the relation between weight and volume.

A study of the ionic equations for several cases of neutralization; the negative ion of the acid and the positive ion of the base are unchanged.

Normal Solutions. (Five periods.)

Calculation of equivalent weights of sulphuric acid and of sodium hydroxide.

Preparation of N/1 solutions (normal solutions) of sulphuric acid and sodium hydroxide.

Experiment to show the proportion by volume in which the above N/1 solutions react to completion.

Simple problems based on neutralization equations.

The Hydrolysis of Salts. (Three periods.)

An experimental study of the reaction on litmus and phenolphthalein of aqueous solutions of (1) salts of a strong base and a weak acid, such as potassium carbonate, borax; (2) salts of a weak base and a strong acid, such as copper sulphate, aluminium chloride; (3) salts of a weak acid and a weak base, such as copper acetate; (4) salts of a strong acid and a strong base, such as sodium chloride.

Elements and Compounds.

The arrangement of the elements and compounds in the following groups is a suggested order of study, but teachers should feel at liberty to teach these in any order they may prefer. It may be found more convenient to study certain compounds with groups other than those with which they are listed; e.g., zinc sulphide could be studied with either Group II or Group VI.

While much of the work covered may seem a review, it is intended to correlate the data into a systematic study of the Periodic Classification. It is also intended that this should be an "experimental study," and the following experiments, with equations, might be considered the minimum.

Where commercial preparations are involved, emphasis should be placed on chemical principles rather than on the plant or the apparatus used. Pupils need not reproduce the diagrams of plant or apparatus.

GROUP I.
Family "A".
Sodium, Potassium.
(Eight periods.)

An experimental study to show:

(1) The action of sodium and potassium on water.
(2) The Solvay method of producing sodium bicarbonate and sodium carbonate.
(3) The use of sodium carbonate (a) to produce insoluble carbonates, (b) to soften water.
(4) The production of ordinary saltpetre from sodium nitrate and potassium chloride.
(5) Potassium permanganate as an "oxidizing agent" with sulphurous acid.

A brief discussion of the relationship between the uses and properties of sodium hydroxide, sodium chloride, sodium carbonate, sodium bicarbonate, potassium nitrate, sodium nitrate, potassium permanganate, and the similarity of sodium and potassium compounds.

Family "B".
Copper,
Silver.

Experiments to show the action of dilute and concentrated acids on copper, as illustrated by sulphuric acid.

A discussion of copper and silver to show such physical properties as conductivity and such chemical properties as inactivity with oxygen.

GROUP VII.
Fluorine,
Chlorine,
Bromine,
Iodine.
(Eight periods.)

An experimental review of chlorine, bromine and iodine: (a) preparation from sodium or potassium compounds, (b) solubility in water, (c) bleaching action, (d) displacement, (e) action of chlorine with sodium, copper, and antimony, (f) action of iodine with phosphorus, (g) colour changes with starch solutions.

Experiments to show the action of concentrated sulphuric acid on sodium (or potassium) chloride, bromide, and iodide.

Discussion of the similarity, (a) in the method of preparation of chlorine, bromine, and iodine, (b) (by reference to formulae only) of their hydrides, (c) the sodium and potassium salts of the aqueous solutions of their hydrides and of their oxygen acids (by reference to formulae only).

Discussion of the gradation of the properties of chlorine, bromine and iodine under (a) physical state, (b) colour, (c) atomic weights, (d) solubility in water, (e) activity, (f) stability of their hydrogen compounds.

A brief reference to fluorine as the most active member of this group.

Principles of the Periodic System.
(Four periods.)

From the study of the elements and compounds of Groups I and VII, discuss the orderly arrangement of the elements in the Periodic Classification.

Stress the importance of this table in the systematic study of chemistry.

Extension of the above to show (i) the law of octaves in relation to the theory of stable octets, and (ii) that related elements in the Periodic Table have similar arrangements of outer electrons and that the valence relations depend on the giving and taking of electrons to form stable electron shells.

GROUP II.
Family "A".
Calcium,
Magnesium.
(Seven periods.)

Experiments to show:

(1) The passing of carbon dioxide into limewater to give (a) calcium carbonate, (b) calcium bicarbonate.
(2) The action of calcium, calcium oxide, calcium carbide, plaster of Paris—with water.
(3) The deliquescence of calcium chloride.

A discussion of the commercial preparation and uses of calcium carbide and calcium cyanamide.

A brief discussion of the relationship between the uses and properties of calcium carbonate, calcium oxide, calcium hydroxide, calcium chloride and gypsum.

A study of the physical properties and uses of magnesium.

A brief reference to the similarity in the properties of magnesium and calcium compounds (e.g., oxides, hydroxides, and carbonates).

Family "B". Zinc.

Experiments to show:

(1) The action of a weak base, such as ammonium hydroxide, on a soluble zinc salt to give zinc hydroxide.

(2) The "amphoteric nature" of zinc hydroxide—by the addition of a strong base and of a strong acid.

A study of the physical properties and uses of zinc.
A brief discussion of the relationship between the uses and properties of zinc oxide and zinc sulphide.

GROUP III.
Aluminium.
(Four periods.)

Experiments to show:

(1) The action of acids and of a strong base on powdered aluminium.

(2) The precipitation of aluminium hydroxide and demonstration of its amphoteric nature by the addition of (a) a strong acid and (b) a strong base.

(3) The reaction of a solution of aluminium sulphate with a solution of sodium bicarbonate.

A brief discussion of the physical properties of aluminium and its importance as a metal.

A brief consideration of the properties and uses of aluminium sulphate in (a) foam-type fire extinguishers, (b) clearing turbid water, (c) as a mordant.

GROUP IV.
Carbon, Silicon, Tin, Lead.
(One period.)

A brief reference to the position of these elements in the Periodic Classification, as midway between Group I and Group VII.

Discuss the transition from non-metallic carbon to metallic lead: (i) in physical properties, and (ii) the acidic and basic properties of their oxides.

GROUP V.
Nitrogen, Phosphorus, Arsenic, Antimony, Bismuth.
(Seven periods.)

An experimental review of ammonia: (a) preparation, (b) solubility, (c) basic properties of its aqueous solution.

Review the preparation of nitric acid (Grade XII).
Experiments to show the oxidizing action of nitric acid on (a) red lead, (b) sulphur.

Experiments to show the preparation of the oxides of phosphorus by burning phosphorus in air, and the formation of phosphoric acid with water.
A demonstration of the properties of the red and yellow allotropes of phosphorus, to show (a) physical properties, (b) kindling temperatures, (c) solubility in carbon disulphide.

A discussion of the industrial production and uses of ammonia (Haber process).

A brief discussion of the relationship between the uses and properties of nitric acid, superphosphate of lime, lead arsenate (insecticides).

Reference to the gradual transition from non-metallic nitrogen to metallic bismuth, and consideration of the similarities (in formulae only) of the oxides and hydrides within the group.

GROUP VI.
Sulphur, Oxygen.
(Seven periods.)

An experimental review of sulphur dioxide: (a) preparation, (b) properties and uses of its aqueous solution.

Experiments to show (a) the oxidizing action of concentrated sulphuric acid on zinc, (b) the dehydrating action of sulphuric acid on sugar or wood, (c) the use of concentrated sulphuric acid in the preparation of other acids.

(a) Demonstration of the preparation and properties of hydrogen sulphide; (b) experimental use of an aqueous solution of hydrogen sulphide (previously prepared by instructor) to precipitate the sulphides of copper, silver, zinc, lead, arsenic, and antimony—from solutions of their salts.

Reference to the use of ammonium sulphide in precipitating sulphides which are soluble in dilute acids (e.g., zinc sulphide).

A brief discussion of the similarity in the chemical behaviour of sulphur and oxygen, as shown by their union with hydrogen and metals to form the sulphides and oxides respectively.

A discussion of (a) the principles involved in the production of sulphuric acid by the Contact Process, and (b) the properties and uses of sulphuric acid.

GROUP VIII.
Iron, Nickel,
Platinum.
(Four periods.)

Experiments to show

(1) The preparation of a ferrous salt by the action of dilute hydrochloric acid on iron.

(2) The preparation of a ferric salt by the action of dilute hydrochloric acid on ferric oxide.

(3) The precipitation of ferrous and ferric hydroxides from their corresponding salt solutions.

(4) The change from ferrous to ferric compounds, as shown by (a) the action of air on ferrous hydroxide, (b) the action of chlorine on a solution of ferrous chloride.

(5) The change from ferric to ferrous compounds, as shown by the action of nascent hydrogen, produced by iron and hydrochloric acid, on a solution of ferric chloride.

A brief reference to the position of iron, nickel, and platinum in the Periodic Classification.

Oxidation and
Reduction.
(Three periods.)

Review (1) oxidation in terms of direct union with oxygen; (2) reduction in terms of the removal of oxygen.

By reference to the experimental work of Group VIII, show that oxidation and reduction can be explained in terms of a change in valence.

Discussion of oxidation as applied to direct union of a metal with any non-metallic element such as sulphur and chlorine.

(a) Recall other oxidizing and reducing agents met previously: potassium permanganate, nitric acid, sulphuric acid, sulphurous acid, carbon; (b) reference to other oxidizing and reducing agents, such as hydrogen peroxide, carbon monoxide, and aluminium (Thermite).

Tests for Common Ions. (Five periods.)

Solubility rules for solutions of the following salts should be memorized: nitrates, chlorides, carbonates, sulphates, and all salts of sodium, potassium and ammonium.

The detection of the following ions in solution: lead, silver, copper, ferrous, ferric, aluminium, zinc, ammonium, nitrate, sulphate, chloride, bromide, iodide, carbonate.

The flame tests for sodium, potassium, calcium.

NOTE.—Explanations of complicated tests for such ions as ferrous, ferric, copper, nitrate, etc., are not essential.

Electrochemical Series. (Three periods.)

Recall relative activity of metals such as sodium, calcium, magnesium, zinc, iron, copper, silver with oxygen, water and dilute acids.

Experiments to show displacement of metals from solutions of their salts.

A brief discussion of the electrochemical series (activity series).

Metallurgy. (Ten periods.)

Occurrence of chemically active metals in combined state.

Occurrence of less active metals in either combined state or free in nature.

Principle of concentration by flotation and sedimentation.

General methods of extraction:

(a) Roasting—sulphides or carbonates of zinc, lead, nickel.
(b) Reduction—oxides of iron, lead, zinc, chromium.
(c) Electrolysis—aluminium, sodium.

Purification by electroylsis—copper, gold.

Metallurgy of iron; blast furnace. Meaning of such terms as smelting, flux, slag, pig iron, wrought iron.

Steel: Bessemer converter, or open-hearth furnace.

Iron alloys such as stainless steel, tool steel, armour plate.

A brief discussion of heat treatment in tempering of steel.

Colloids. (Four periods.)

Illustration of the rate of sedimentation and particle size by an experiment such as the following: Shake some sandy loam soil with water in a tall jar and observe the relationship between the time taken for order of deposition and size of particles as indicated by the stratification of the deposit.

A demonstration of the preparation of colloidal dispersions such as starch in water or arsenic trisulphide in

water and the presence of the diffused particles shown by a beam of light—Tyndall effect.

Show that the dispersion will pass through a filter paper and still exhibit the Tyndall effect.

Comparison of the properties of solutions and suspensions, and show from the properties of a colloidal dispersion such as arsenious sulphide that it lies in an intermediate position.

Common occurrence of colloids such as protoplasm in plant and animal cells, egg white, jellies, glue, clay, fog, smoke, skim milk and homogenized milk.

Organic Chemistry. (Eighteen periods.)

NOTE.—The molecular formulae of the compounds marked with an asterisk (*) are the only ones required. Only a brief discussion of the commercial preparations of organic compounds is expected, except where experiments are indicated.

A brief review of carbon and its compounds. Reference to the division of chemistry into Organic and Inorganic Chemistry. Organic compounds when completely oxidized form carbon dioxide and water.

HYDROCARBONS:

Methane*. Occurrence and uses of methane. The methane series (paraffins). A brief discussion of the structural formulae of the members of this series to show their relationship, and likewise the substitution derivatives of methane—methyl chloride*, chloroform* and carbon tetrachloride*.

Petroleum. A demonstration to show fractional distillation by the separation of methyl alcohol, water and caramel, or some non-volatile colouring matter. A discussion of the fractional distillation and refining of petroleum into naphtas, kerosene, lubricating oils and vaseline.

Acetylene series. The preparation, properties and uses of acetylene*. A brief discussion of the acetylene series.

CARBOHYDRATES:

A brief discussion of the composition and properties of carbohydrates—sugars, starch and cellulose, and of their production in plants by photosynthesis.

Sugars. Sucrose*—experiment to show inversion into simple sugars such as glucose*. Lactose*.
Oxidation (burning) of glucose within living cells with liberation of energy (metabolism).

Starch*. Characteristics of starch. Hydrolysis of starch into simple sugars such as glucose. Reference to action of saliva on starch.

Cellulose*. Characteristics of cellulose. Cellulose products—nitrates, rayon, cellophane.

ALCOHOLS:

Relationship of structural formula of alcohols to the hydrocarbons. General properties of alcohols.

Methyl alcohol*. Discussion of preparation by (a) destructive distillation of hard wood, (b) synthetic method from carbon monoxide and hydrogen. Properties and commercial uses.

Ethyl alcohol*. Experiment to show the preparation of ethyl alcohol by the action of yeast on a 10% glucose solution (corn syrup diluted).

Glycerol (as an alcohol).

ORGANIC ACIDS:

A brief discussion of organic acids; fatty acid series. Reference to preparation and uses of acetic acid.

Reference to the acids of other series—lactic acid, oxalic acid, tartaric acid and citric acid.

OILS AND FATS:

Recall the properties and tests for fats (Grade X).

A brief discussion of animal and vegetable oils and fats as esters of fatty acids.

Soap and soap making. Hydrogenation of oils (olein). An experiment to show the emulsifying power of soap.

The cleansing action of soap. Experiment to show the action of hard water on soap.

PROTEINS:

Complex organic compounds containing nitrogen.

Recall the properties and tests for proteins (Grade X).

Examples: hair, flesh, natural silk, legumes, milk (casein and albumin), gelatin, egg white.

RECOMMENDED TEXT-BOOKS

High School Chemistry. Bruce. Renouf Publishing Co.
Chemistry at Work. McPherson and Henderson. Ginn & Co.
A First Book in Chemistry. Bradbury. Ryerson Press.
Senior Chemistry for Canadian High Schools and Colleges. Cornish. Copp, Clark Co., Ltd.
Introductory College Chemistry. Alexander Smith, Ryerson Press.
General Chemistry for Colleges. Briscoe. Renouf Publishing Co.
Dominion High School Chemistry. Bigelow, Morehouse. Macmillan Co.
Elementary Chemistry. Book II. Littler. Clarke, Irwin and Co.